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Full Length Article

Combining Ability Analysis for Yield and Yield Related Traits among Wheat Varieties and their F_1 Hybrids

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ABSTRACT

Breeding wheat for high yield and other desirable traits is a dire need of the day. Main focus during wheat breeding programme is the selection of desirable wheat varieties used as parents for production of gene combinations containing high yield and other superior traits. Combining ability analysis was done following Griffing approach (1956) for 7 × 7 complete diallel among Shahkar-95, Parwaz-94, Iqbal-2000, Uqab-2000, MH-97 4072 and Punjab-96. Various plant phenotypic traits like plant height, flag leaf area, number of tillers per plant, peduncle length, extrusion length, spike length, spikelet per spike, spike density, grains per spike, 1000-grains weight and grains yield per plant were investigated. Significant differences appeared for genotypes, general combining ability (GCA) specific combining ability (SCA) and reciprocal effects. The greater magnitude of σ2g than σ2s for all the traits except for plant height and grain yield per plant depicted the importance of additive gene action in inheritance of the traits. Involvement of non-additive gene action was evident in the inheritance of plant height and grain yield per plant. Punjab-96, Uqab-2000, Iqbal-2000 and MH-97 appeared to be best general combiners for almost all the plant traits, respectively and hybrids Iqbal-2000 × Parwaz-94, Parwaz-94 × Uqab-2000 and Punjab-96 × 4072 seemed to be best specific combiners.

Key Words: Combining ability; Gene action; Spring wheat; Diallel

INTRODUCTION

For any breeding programme aiming at hybridization, knowledge of better combiner parents is a prerequisite. It is important to achieve genetic gain within limited resources and minimum time. For this purpose, basic knowledge of genetic architecture of yield and yield components and nature of gene action is required. Among various genetic techniques, combining ability analysis developed by Griffing (1956) is perquisite for important information for selection of parents in terms of the performance of their hybrids. Further it elucidates the nature and magnitude of various types of gene actions involved in the expression of quantitative characters.

Yield is a polygenic trait and is greatly influenced by the environmental changes. Any improvement in yield and its related characteristics like plant height, flag leaf area, spike length, number of spikelets per spike, number of grains per spike and spike density through selection and breeding would help to improve unit area production. An enormous deal of research work on the study of combining ability of different plant characters of wheat has been done by many researchers. Combining ability in a complete diallel cross of wheat varieties was studied by Chowdhry and Ahmad (1990) who noted that number of tillers per plant and spike length were significant for reciprocal effects.

Sharma *et al.* (1986), Chowdhry *et al.* (1982) and Prodanovic (1993) concluded that additive gene action was important for spike length. Chowdhry *et al.* (1989) and Khan *et al.* (1992) revealed that gene action for number of grains per spike was additive type. According to Chaudhry *et al.* (1994) additive type of gene action was prominent in plant traits like flag leaf area, number of spikes per plant, spikelets per spike and grain yield per plant, while non-additive type of gene effect was important in controlling plant height, peduncle length and 1000-grains weight. While both additive and non-additive gene effects were important in the inheritance of most of the traits like grain yield per plant, spikelets per spike, grains per spike, 1000-grains weight, fertile tillers per plant and plant height (Singh & Chatrath, 1997).

Wheat (*Triticum aestivum* L.) is the most valuable staple food and regarded in the world as king of cereals. It is a big source of caloric and other nutrients for about 149.03 million people of Pakistan with per capita availabilty of wheat as 140.88 kg per annum (Anonymous, 2003). It plays a most significant role in critical areas of food security and economic stabilty in the country. Main objective of present study is to identify the best combiners and their crosses on the basis of their general and specific combining ability for yield and its component traits.

MATERIALS AND METHODS

The research work presented was carried out in the

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experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan. Under field conditions, soil pH was 6.5, EC 4 dS m^{-1} and photoperiod for wheat was 10 h in November, 2004. The experimental material used in the present studies consisted of seven wheat varieties/lines; Shahkar-95, Parwaz-94, Iqbal-2000, Uqab-2000, MH-97, 4072 and Punjab-96. The seeds of seven wheat parents were sown in the field and later hybridized at heading stage to develop genetic material for genetic studies. After emasculation the entire spike was covered with a glycine bag. For hybridization, spike of the plant was emasculated by removing anthers from flowers within spike. Next day, early in the morning, the emasculated spikes were hand pollinated by applying fresh pollen from the requisite male parent and covered again with its respective bag till seed setting. At maturity, F_0 seeds from all the crosses were collected.

During next crop season, seven wheat varieties/lines (parents) and their hybrids (F1) were planted in the field following a triplicated randomized complete block design. Thirty plants of each genotype were grown in a 5 m long row in each replication. The plants were spaced 15 and 30 cm apart within and between the rows, respectively. To keep uniformity in the distance and depth of the seeds, a template was used. Two seeds were dibbled per hole and after germination one healthy seedling was retained at each hole through thinning. Standard agronomic practices including hoeing, weeding, irrigation etc., were adopted uniformly. Ten guarded plants were selected randomly from each row for the following traits viz., plant height, flag leaf area, number of tillers per plant, peduncle length, extrusion length, spike length, number of spikelets per spike, spike density, number of grains per spike, 1000-grains weight and grains yield per plant.

Data were subjected to analysis of variance according to Steel *et al.* (1996) to find significant differences among genotypes for the recorded data. After obtaining the significant differences, data were further analyzed as per Griffing (1956) method I and model II.

RESULTS AND DISCUSSION

This study evaluated the genetic variability among seven wheat varieties/lines and their F1 hybrids, selected on the basis of maturity period and high yield characters. These genotypes and their F1 hybrids showed variability in their genetic architecture. All genotypes differed significantly ($P \sim 0.01$) for traits like plant height, flag leaf area, number of tillers per plant, peduncle length, extrusion length, spike length, number of spikelets per spike, spike density, number of grains per spike, 1000-grains weight and grain yield per plant (Table I). Significant differences among genotypes for grain yield and related traits in different sets of material of wheat have been reported (Menon & Sharma, 1997; Ambreen *et al.,* 2002).

After obtaining significant differences among genotype for various traits, combining ability analysis was done to perceive superior progeny when one parent combined with another parent. General combining ability (GCA) provided an estimation of degree of additive gene action and specific combining ability (SCA) exhibited the performance of two particular varieties/lines in a specific cross, which would reflect non-additive type of gene action (Phoelman & Sleper, 2006).

Analysis of diallel cross data using combining ability approach (Griffing, 1956) showed that total variation among the genotypes was partitioned into variation due to general and specific combining ability and reciprocal effects. Mean squares for GCA, SCA and reciprocal effects were highly significant ($P \leq 0.01$) for all the traits (Table II) but value for $\sigma 2$ g was higher for flag leaf area, number of tillers per plant, peduncle length, extrusion length, spike length, number of spikelets per spike, spike density, grains per spike than that of $\sigma 2$s except for plant height and 1000-grains weight (Table II). Thus, additive type of gene action was more prominent for the said traits but non-additive genetic effect was important in case of plant height and grain yield per plant. These findings are comparable with most of the earlier reports in wheat (Kronstad & Foote, 1964; Brown *et al.,* 1966; Iqbal & Khan, 2006). Asad *et al.* (1992), Khaliq *et al.* (1992), Ali and Khan (1998), Masood and Kronstad (2000), Mahmood and Chowdhry (2002) and Chowdhry *et al.* (1999) and found that most of the variations in yield and related traits in Fl hybrids in wheat were associated with the high general combining ability rather than specific combining ability. Ali and Khan (1998) further reported significant reciprocal effects for plant height and other yield related traits but non-significant reciprocal effect was important in flag leaf area.

Most of the plant traits in this study were controlled by additive type of gene action (Table II). These findings are in agreement with observations of Khan and Ali (1998) and Hamada *et al.* (2002) while non-additive type of gene action was involved in controlling number of spikelets per spike (Rehman *et al.,* 2002). Both additive and non-additive gene effects were involved in controlling the plant traits. Zubair *et al.* (1987) and Whitehouse *et al.* (1958) also observed that gene interactions were important for grain yield per plant.

Plants with short stature were considered desirable being nitrogenous responsive and resistant to lodging ultimately high yield was achieved. Three of seven parental genotypes in case of plant height, Parwaz-94 (-2.27) followed by Shahkar-95 (-1.71) and Iqbal-2000 (-0.86) displayed maximum negative GCA effects (Table III). Parwaz-94 was considered the best general combiner for plant height. Other four parents exhibited positive GCA effects in this case. Out of twenty one, only six crosses for specific combining ability showed negative specific combining ability, while remaining 15 crosses showed positive specific combining ability. Highest negative SCA effect in hybrids Iqbal-2000 × MH-97 (-2.64) and Iqbal-2000 × Uqab-2000 (-2.12) was recorded. Highest positive SCA effect was found in the cross of Parwaz-94 × Uqab-2000. Out of 21 reciprocal effects, only

Table I. Mean squares of various plant traits in 7×7 diallel cross of wheat

Source	DF	Plant height	Flag leaf area	No. of tillers per plant	Peducle length	Extrusion length	Spike length	Spikelets per spike	Spike density	Grains per spike	1000 grains weight	Grain yield per plant
Reps.	2	17.94	4.21	1.16	2.55	2.75	1.83	2.22	0.039	16.47	5.81	2.23
Genotype	48	41.38**	21.77**	1.61**	13.69**	12.11**	1.54**	1.96**	0.037**	62.39**	12.43**	9.12**
Error	96	9.47	2.25	0.84	2.36	2.37	0.71	1.014	0.013	27.43	6.251	3.08
Mean		71.025	15.184	8.785	31.05	14.946	10.75	18.179	1.702	53.531	35.376	20.043
CV%		4.101	9.873	10.44	4.94	10.286	7.828	5.538	6.803	9.783	7.067	8.764

**, Significant at P≤0.01; *, Significant at P≤0.05; NS, Non-significant at P>0.05

six hybrids showed negative effects. The hybrids Parwaz-94 × MH-97 (-1.47) and Iqbal-2000 × 4072 (-1.47) showed highest negative reciprocal effects for plant height. Maximum positive reciprocal effect was found in Parwaz-94 × Punjab-96 (4.50) (Table III).

Flag leaf area indicated four out of seven parental genotypes exhibited positive general combining ability (Table III). Out of 21 hybrids for SCA, The maximum positive GCA effects were found in Punjab-96 (2.36) followed by Iqbal-2000 (1.71). It showed that Punjab-96 was best general combiner for flag leaf area. Highest positive SCA effects were found in Iqbal-2000 × Punjab-96 (1.72) and Shahkar-95 × Uqab-2000 (0.82), respectively. The indirect or reciprocal effects were found in Iqbal-2000 × Parwaz-94 (2.78) and MH-97 × Shahkar-95 (1.0), which displayed maximum positive reciprocal effects.

Five out of seven genotypes showed positive GCA for number of tillers per plant, while remaining two exhibited negative GCA effects. Maximum positive GCA effects (0.67) were recorded in the genotype MH-97 being the best general combiner for number of tillers per plant. The genotype Shahkar-95 was considered the poorest general combiner with GCA (-0.60). Number of hybrids showing positive SCA effects were 11 out of 21. Maximum value (0.61) for specific combining ability was observed in Shahkar-95 × MH-97 followed by Iqbal-2000 × 4072 (0.32). Positive and highest reciprocal effects were found in crosses Shahkar-95 × Iqbal-2000 (1.37) and 4072 × Iqbal-2000 (0.75).

Three of seven genotypes like Punjab-96 (2.29), MH-97 (0.09) and Iqbal-2000 (0.07) displayed positive GCA effects for peduncle length. Punjab-96 had maximum dominant genes for peduncle length, because it possessed maximum positive GCA effect. Highest negative GCA was found in Parwaz-94 (-1.83). Similarly, maximum positive SCA effect was recorded in hybrid 4072 × Punjab-96 (1.46) for peduncle length. Maximum positive indirect or reciprocal effect was found in Uqab-2000 × Shahkar-95 (2.20).

Four out of seven genotypes for extrusion length showed positive GCA. Punjab-96 (1.81) and Iqbal-2000 (0.34) were the best general combiners for extrusion length. The poorest general combiner was Parwaz-94 (-1.19) with maximum negative GCA effects. Positive SCA effects were recorded in 12 out of 21 crosses. Crosses showing positive and maximum specific effects were Iqbal-2000 × Punjab-96 (1.37) and Parwaz-94 × 4072 (1.33), respectively were thought to be the best specific combiner for extrusion length. Reciprocal effects were positive in 17 crosses out of 21 being maximum in the cross Uqab-2000 × Parwaz-94 (2.94).

Table II. Estimates of variation components of general (σ^2g), specific (σ^2s) combining ability, reciprocal effects (σ^2r), error (σ^2e) and GCA/SCA ratios in a 7X7 diallel cross of wheat

Traits	σ^2g	σ^2s	σ^2r	σ^2e	GCA/SCA
Plant height (cm)	2.80	4.04	2.02	3.14	0.69
Flag leaf area (cm^2)	2.93	0.68	0.82	0.75	4.13
No. of tillers per plant	0.15	-0.09	0.08	0.28	-11.11
Peducle length (cm)	1.54	0.47	0.70	0.79	3.27
Extrusion length (cm)	0.91	0.41	1.42	0.79	2.22
Spike length (cm)	0.14	-0.02	0.05	0.24	-7
Spikelets per spike	0.15	0.08	0.17	0.34	1.87
Spike density	5.94	-2.72	4.49	9.14	-2.18
Grains per spike (g)	0.002	0.004	0.002	4.47	5
1000-grains weight (g)	1.31	0.49	0.29	2.08	2.67
Grain yield per plant (g)	0.57	-5.26	1.21	1.03	-0.11

Three out of seven genotypes possessed positive GCA effects for spike length. Maximum GCA effects were found in Punjab-96 (1.47), Uqab-2000 (0.35) and Iqbal-2000 (0.34) respectively. Eleven out of 21 crosses showed positive SCA effects. Cross Parwaz-94 × Uqab-2000 (0.51) possessed maximum genes for spike length. Maximum reciprocal effect was found in Punjab-96 × Shahkar-95 (0.73).

Five out of seven exhibited positive GCA effects for number of spikelets per spike. Three of seven parental genotype, Parwaz-94 (-2.27), Shahkar-95 (-1.71) and Iqbal-2000 displayed negative GCA effects (Table-III). The best general combiner having greatest GCA effects (0.45) was Uqab-2000. The genotype Parwaz-94 had maximum negative GCA effects (-0.76). Combinations showing highest positive SCA effects were Parwaz-94 × Uqab-2000 (0.49), Parwaz-94 × Iqbal-2000 (0.34) and 4072 × Iqbal-2000 (0.34). Reciprocal effects were positive in 21 crosses, while the crosses MH-97 × Iqbal-2000 (1.07) and 4072 × Shahkar-95 (0.97) showed maximum positive reciprocal effects.

Maximum positive GCA effects were found in 4072 (0.041) and MH-97 (0.038), Shahkar-95 (0.28) and Parwaz-94 (0.28). So, 4072 was considered the best general combiner for spike density. While Iqbal-2000 (-0.079) was considered the poorest general combiner for spike density. Best cross combinations showing high positive SCA effects were Parwaz-94 × Punjab-96 (0.087) and MH-97 × Punjab-96 (0.074) and Shakar-95 × Iqbal-2000 (0.066). MH-97 × Parwaz-94 (-0.079) possessed maximum negative SCA effect for spike density. The indirect or reciprocal effects in MH-97 × Iqbal-2000 (0.122) and Punjab-96 × MH-97 (0.119) were found high.

Table III. General combining ability (diagonal), specific combining ability (above diagonal) and reciprocal (below diagonal) effetcs of seven wheat genotypes and their crosses

Genotypes	Shahkar-95	Parwaz-94	Iqbal-2000	Uqab-2000	MH-97	4072	Punjab-96
Plant height							
Shahkar-95	-1.71	-1.96	-0.56	1.77	0.84	0.15	1.71
Parwaz-94	-0.30	-2.27	0.29	1.69	0.47	2.09	1.87
Iqbal-2000	0.23	3.73	-0.86	-2.12	-2.64	0.20	3.79
Uqab-2000	1.00	-0.32	0.38	1.93	0.55	0.68	-2.03
MH-97	1.27	-1.47	1.23	0.62	0.04	3.37	0.05
4072	1.77	2.38	-1.47	2.97	3.27	-0.24	-0.81
Punjab-96	-0.30	4.50	1.10	1.50	0.58	0.25	2.93
	$S.E(g_i)$=0.44		$S.E(s_{ij})$=1.09		$S.E.(r_{ij})$=1.26		
Flag leaf area							
Shahkar-95	-2.32	0.46	-1.47	0.82	0.22	0.34	-1.12
Parwaz-94	0.40	-1.91	-1.29	0.56	0.15	0.01	-1.52
Iqbal-2000	0.16	2.78	1.71	-1.13	-0.60	0.21	1.72
Uqab-2000	0.39	-0.32	0.83	-0.61	-0.15	-0.09	0.53
MH-97	1.00	0.28	0.54	-0.80	0.06	0.15	0.45
4072	-0.02	0.01	-1.64	-0.73	-2.56	0.71	-0.98
Punjab-96	-1.62	0.09	-0.30	-1.24	-0.20	0.31	2.36
	$S.E(g_i)$= 0.21		$S.E(s_{ij})$= 0.53		$S.E.(r_{ij})$=0.61		
Number of tillers per plant							
Shahkar-95	-0.60	-0.18	-0.36	0.004	0.61	0.10	-0.25
Parwaz-94	0.32	0.15	-0.01	0.04	0.06	0.07	0.09
Iqbal-2000	1.37	0.40	0.01	0.06	-0.15	0.32	0.14
Uqab-2000	-0.57	-0.20	0.10	0.04	-0.33	-0.16	0.19
MH-97	0.53	0.17	0.12	-0.17	0.67	-0.20	-0.25
4072	0.15	0.17	0.75	0.13	-0.45	-0.37	-0.08
Punjab-96	-0.70	0.05	0.47	0.45	-0.13	-0.43	0.11
	$S.E(g_i)$= 0.13		$S.E(s_{ij})$= 0.32		$S.E.(r_{ij})$= 0.30		
Peducle length							
Shahkar-95	-0.35	-0.07	0.33	-0.25	0.74	-0.79	1.17
Parwaz-94	0.66	-1.83	1.05	1.07	1.34	-0.67	-1.34
Iqbal-2000	-0.14	1.17	0.07	-0.81	-0.23	-0.25	0.33
Uqab-2000	2.20	0.40	-0.86	-0.61	-0.38	0.94	0.04
MH-97	0.90	0.55	-0.24	-0.30	0.09	-0.23	-1.35
4072	0.45	-0.83	0.52	0.62	-0.24	-0.88	1.46
Punjab-96	1.67	-0.83	1.25	1.00	-2.12	-0.42	2.29
	$S.E(g_i)$= 0.22		$S.E(s_{ij})$= 0.54		$S.E.(r_{ij})$= 0.63		
Extrusion length							
Shahkar-95	-1.05	0.31	-0.05	-0.61	0.29	-0.66	0.36
Parwaz-94	-0.50	-1.19	-0.79	-0.45	0.93	1.33	0.25
Iqbal-2000	0.20	0.32	0.34	0.49	-0.18	0.42	1.37
Uqab-2000	0.83	2.94	1.40	0.07	0.79	0.55	0.49
MH-97	0.78	0.28	-0.13	0.17	-0.33	-0.36	-1.28
4072	0.00	1.34	0.60	1.07	-1.32	-0.32	-0.02
Punjab-96	0.31	1.50	2.52	0.67	-3.17	1.23	1.81
	$S.E(g_i)$= 0.22		$S.E(s_{ij})$= 0.54		$S.E.(r_{ij})$= 0.63		
Spike length							
Shahkar-95	-0.13	0.19	-0.34	-0.28	0.19	-0.11	0.30
Parwaz-94	0.13	-0.61	0.39	0.51	0.39	-0.46	-0.60
Iqbal-2000	-0.25	0.20	0.34	-0.08	-0.07	0.02	-0.01
Uqab-2000	-0.48	0.00	-0.46	0.35	-0.02	0.12	-0.07
MH-97	0.38	-0.67	-0.17	0.12	-0.19	0.16	-0.36
4072	-0.05	-0.12	-0.55	0.00	0.17	-0.22	0.47
Punjab-96	0.73	0.00	-0.18	0.50	-1.00	-0.50	1.47
	$S.E(g_i)$= 0.12		$S.E(s_{ij})$= 0.30		$S.E.(r_{ij})$= 0.34		
Spikelets per spike							
Shahkar-95	0.09	-0.44	0.17	-0.10	0.14	-0.01	0.05
Parwaz-94	-0.27	-0.76	0.34	0.49	-0.08	-0.39	-0.08
Iqbal-2000	-0.12	0.90	-0.26	-0.34	-0.06	0.34	-0.78
Uqab-2000	-0.38	-0.03	0.03	0.45	-0.15	-0.07	0.19
MH-97	-0.15	-1.18	1.07	-0.05	0.07	0.10	0.09
4072	0.97	-0.47	-0.03	0.67	-0.12	0.10	0.09
Punjab-96	0.95	0.60	0.23	0.45	-0.50	-0.33	0.31
	$S.E(g_i)$= 0.14		$S.E(s_{ij})$= 0.36		$S.E.(r_{ij})$= 0.41		

Table III. Continues

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Spike density							
Shahkar-95	0.028	-0.063	0.066	0.037	-0.010	0.015	-0.048
Parwaz-94	-0.037	0.028	-0.037	-0.038	-0.079	0.040	0.087
Iqbal-2000	0.031	0.054	-0.079	-0.013	0.006	0.027	-0.068
Uqab-2000	0.049	0.003	0.071	-0.016	-0.012	-0.023	0.028
MH-97	-0.070	0.009	0.122	-0.025	0.038	-0.019	0.074
4072	0.102	-0.026	0.083	0.016	-0.051	0.045	-0.076
Punjab-96	-0.022	0.062	0.043	-0.037	0.119	0.042	-0.044
	$S.E(g_i)$= 0.0003		$S.E(s_{ij})$= 0.003		$S.E.(r_{ij})$= 0.002		
Number of grains per spike							
Shahkar-95	-2.81	-0.99	0.11	-2.55	0.27	1.29	0.93
Parwaz-94	-3.70	-0.09	1.59	1.77	-0.54	-0.02	-1.95
Iqbal-2000	-3.37	4.70	-2.13	-0.91	0.92	-1.01	0.68
Uqab-2000	2.97	2.67	-2.97	2.79	2.83	0.35	-0.87
MH-97	-1.67	2.77	-1.33	-0.50	-1.66	-0.96	-2.52
4072	1.23	0.83	0.85	1.57	2.33	0.09	0.90
Punjab-96	-5.47	-2.97	-0.23	-5.60	-0.17	5.00	3.82
	$S.E(g_i)$=0.75		$S.E(s_{ij})$=1.86		$S.E.(r_{ij})$=2.14		
1000-grains weight							
Shahkar-95	-1.59	-0.39	0.96	1.48	0.75	-0.78	-0.62
Parwaz-94	0.17	-0.96	0.12	-0.96	-0.18	0.14	1.80
Iqbal-2000	1.32	2.27	-0.05	-0.49	-0.12	-0.10	-0.37
Uqab-2000	-0.60	0.03	1.21	1.37	-0.83	0.97	-0.17
MH-97	-1.23	1.53	-0.77	-0.78	-0.43	0.45	-0.15
4072	0.28	0.01	0.74	-0.90	0.02	-0.02	-0.55
Punjab-96	0.59	2.33	-2.13	1.20	0.98	-0.02	1.68
	$S.E(g_i)$=0.35		$S.E(s_{ij})$=0.89		$S.E.(r_{ij})$=1.02		
Grain yield per plant							
Shahkar-95	0.47	0.30	-0.90	0.43	-0.59	0.03	-0.36
Parwaz-94	-0.28	0.42	-0.38	-0.82	-1.18	0.55	0.66
Iqbal-2000	-1.59	1.41	-1.09	0.54	0.18	0.26	0.07
Uqab-2000	-0.28	-1.12	0.34	0.07	0.23	-0.50	0.07
MH-97	-1.89	-0.33	0.70	-0.94	0.82	-0.17	-0.41
4072	-1.59	0.39	1.93	1.86	0.14	0.47	0.63
Punjab-96	1.25	0.29	0.62	0.02	2.65	-2.49	-1.17
	$S.E(g_i)$=0.25		$S.E(s_{ij})$=0.62		$S.E.(r_{ij})$=0.72		

In case of number of grains per spike (Table III), three of seven parental genotypes showed positive GCA effects i.e., Punjab-96 (3.82), Uqab-2000 (2.79) and 4072 (0.09) displayed positive GCA effects. The genotypes Punjab-96 had maximum dominant genes for number of grains per spike, because it possessed maximum positive GCA effect. Out of 21 crosses, only eleven hybrids showed positive SCA effects. Best cross combinations showing high positive SCA effects were Uqab-2000 × MH-97 (2.83), Parwaz-94 × Uqab-2000 (1.77) and Parwaz-94 × Iqbal-2000 (159). Only 10 positive reciprocal effects were observed out of twenty one. Maximum reciprocal effects were observed in Punjab-96 × 4072 (5.00), Iqbal-2000 × Parwaz-94 (4.70) and Uqab-2000 × Iqbal-2000 (2.97).

Only two out of seven parental genotypes were positive, while remaining five genotypes were negative for 1000-grain weight (Table III). Highest GCA effects were found in Punjab-96 (1.68) and Uqab-2000 (1.37). Eight out of 21 cross combinations were positive and among them, Parwaz-94 × Punjab-96 (1.80), Shahkar-95 × Uqab-2000 (1.48) and Uqab-2000 × 4072 (0.97) showed highest SCA effects for 1000-grains weight. Maximum positive reciprocal effects were recorded in Punjab-96 × Parwaz-94 (2.33), Iqbal-2000 × Parwaz-94 (2.27) and MH-97 × Parwaz-94 (1.53).

Five out of seven parental genotypes had positive general combining ability for grain yield per plant (Table III). MH-97 showed highest positive GCA effects (0.82), which showed the best general combiner for grain yield per plant. Punjab-96 had negative GCA effect (-1.17), which proved to be the poorest general combiner for grain yield per plant. Maximum SCA effects were found in Punjab-96 × Parwaz-94 (0.66) and Punjab-96 × 4072 (0.63). Twelve out of 21 positive reciprocal effects were observed, having maximum positive effects in Punjab-96 × MH-97 (2.65) 4072 × Iqbal-2000 (1.93).

CONCLUSION

Parent like Punjab-96 proved as a best general combiner for flag leaf area, peduncle length, extrusion length, spike length, number of grains per spike and 1000-grains weight. Uqab-2000 was also found as best general combiner for number of spikelets per spike, flag leaf area, number of grains per spike and 1000-grains weight and MH-97 for number of tillers per plant, grain yield per plant and spike density. These three parents can be used in hybridization program for obtaining desirable combinations.

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